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ECOLOGICAL FACTORS IN NORTH TEXAS RELATED TO THE 1935 STEM RUST EPIDEMIC

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UNITED STATES DEPARTMENT OF AGRICULTURE

ECOLOGICAL FACTORS IN NORTH TEXAS RELATED TO THE 1935 STEM RUST EPIDEMIC [1]

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Introduction

Stem rust (Puccinia graminis tritici Eriks. and Henn.) is one of the most destructive and widespread diseases attacking the wheat plant. Official estimates of losses from stem rust in the United States may be obtained from various sources and will not be given here. The 1935 epidemic was one of the most destructive in history and extended over most of the wheat-growing areas of the United States.

The two wheat rusts, stem rust (Puccinia graminis tritici) and leaf rust (Puccinia triticina) are of major economic importance in Texas. These diseases limit the production of wheat in Texas to the more north-central parts of the State and to regions of lower rainfall in the western part, where rust usually is not a factor. The estimated annual loss from stem rust in Texas from 1925 to 1934 was 359,000 bushels, while that caused by leaf rust was 388,200 bushels [3]. Stem rust is every year a limiting factor in wheat production from central Texas southward. In north-central Texas the disease is present nearly every year, but often is not a major factor in yield because of the early maturity of the crop. Because of the extensive wheat acreage, however, this area serves as a breeding ground for stem rust and increases the inoculum to be carried northward as the season progresses. During mild winters stem rust may actually overwinter in this area.

1/ A report of cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Texas Agricultural Experiment Station at Texas Substation No. 6, Denton, Texas.

2/ Thanks are due Mr. P. B. Dunkle, Superintendent of Substation No. 6, Denton, Texas, and the Texas Agricultural Experiment Station for permission to use unpublished meteorological data as given in this report.

3/ United States Department of Agriculture, Bureau of Plant Industry, Division of Mycology and Disease Survey, Plant Disease Reporter Supplements 49, 56, 64, 83, 87, and 89. Reports of losses from diseases in the United States for the years 1925 to 1934 inclusive.

Rainfall for the month of April was about normal in total amount but it all occurred after April 18. Previous to this there was a time interval in March and April when there was insufficient moisture for the crop. During that period conditions were not favorable for rust infection. After rains started in April, both humidity and temperature were favorable for rust infection and spread.

A total of 11.52 inches of precipitation was recorded during May, a record amount for that month. A measurable amount of precipitation occurred on 13 days of the month. This unusual amount of moisture promoted continued growth of the wheat crop for a longer than normal period, and thus delayed heading and maturity. Associated with the large amount of precipitation of May were extremely high relative humidity and subnormal temperatures. The mean daily humidity did not fall below 66 percent at any time during the month. The mean, 83.2 percent, for the month is 13.3 percent above normal. The conditions, therefore, were favorable for rust infection throughout the month.

Because of extremely late maturity of the crop, June weather was a factor in rust development this season, whereas, normally, it would not be. Precipitation in June was 5.27 inches compared with the normal of 2.85 inches. The relative humidity was never below 64 percent and the mean relative humidity of 77. percent was 13.4 percent above normal.

From the above study of humidity and precipitation during the period when the wheat plants were susceptible to rust, it is evident that conditions were extremely favorable in 1935 for the development of a rust epidemic. The excessive precipitation and high humidity contributed much to the delay in ripening of the grain and thus furnished ample time for the epidemic to develop in northern Texas and provide inoculum for the continued spread of the disease in other states.

Temperature and Humidity at Time of the Morning Reading: Environmental factors are usually most favorable for rust infection early in the morning. Because of this it was considered desirable to study, in addition to mean daily temperatures and relative humidity, the temperature and humidity at the morning reading. This reading is taken at 7 o'clock. In Figure 3 the relative humidity and temperature at the morning reading for the period April 1 to June 30 are shown. Days on which dew occurred are shown also.

Previous to April 18 conditions were not very favorable for germination of rust spores. Temperatures were favorable on certain days, but often when the temperature was favorable, the humidity was fairly low. Dews also were less frequent than later in the season.

Table 1. Climatological data recorded at Texas Substation No. 6, Denton, Texas, for the years 1931 to 1935, inclusive, and averages 1914 to 1935.

	1931			1932			1933			1934			1935			Average 1914-1935		
	Apr.	May	June	Apr.	May	June	Apr.	May	June	Apr.	May	June	Apr.	May	June	Apr.	May	June
Mean maximum temperature	71.9	78.5	93.7	78.7	81.9	90.8	79.4	84.6	93.7	76.3	84.8	97.6	75.7	77.0	87.1	76.0	81.0	91.8
Mean minimum temperature	47.4	55.2	68.6	52.0	59.7	69.9	50.5	63.5	66.2	54.4	60.0	71.9	51.6	59.0	66.4	51.8	59.9	68.8
Mean monthly temperature	59.7	66.8	81.2	65.4	70.8	79.8	64.9	74.1	80.0	65.6	72.4	84.8	63.7	68.0	76.8	63.9	70.8	80.1
Mean relative humidity	74.7	74.6	63.8	64.1	74.3	73.8	60.3	73.4	56.1	72.2	66.1	50.7	72.0	83.2	77.9	67.1	72.0	64.5
Total evaporation-inches	4.02	5.24	7.40	5.66	5.61	6.48	5.84	5.91	8.43	4.68	6.21	10.1	4.47	4.67	6.23	5.09	5.65	7.51
Total precipitation-inches	1.71	2.19	1.37	1.96	4.57	4.82	2.24	5.22	.05	4.19	4.24	.23	3.54	11.52	5.27	3.82	4.63	2.85
Number days with .01 inch or more:	8	8	7	6	7	9	5	8	1	8	6	1	10	13	10	7.9	8.4	6.5
Number of precipitation	8	8	7	6	7	9	5	8	1	8	6	1	10	13	10	7.9	8.4	6.5
Number of clear days	12	14	15	16	16	14	16	16	28	12	21	30	13	11	14	13.7	14.6	17.8
Number of cloudy days	8	7	2	5	9	1	2	7	0	8	6	0	10	11	8	6.8	6.8	2.7
Number partly-cloudy days	10	10	13	9	6	15	12	8	2	10	4	0	7	9	8	9.6	9.6	9.5
Number days dew	16	16	10	8	19	18	15	20	16	19	26	4	10	22	21	-	-	-
Mean monthly daily wind movement	138	136	143	227	138	164	176	157	121	166	128	337	212	192	149	243	183	176
Number days wind from south (include SE and SW):	13	13	25	19	11	17	14	17	23	18	17	28	17	20	21	17.7	19.1	23.9
Date on which first stem rust was observed		20			9			17			11			7				
Percentage of rust in 18 wheat varieties			7			25			28			19			82			
Average-%																		
Range -%		0 to 27			1 to 51			0 to 63			0 to 65			20 to 99			

Table 2. Total daily wind run at Texas Substation No. 6, Denton, Texas, during April, May, and June, 1935 with comparisons with normal.

Date	April Total wind run	April Direction	May Total wind run	May Direction	June Total wind run	June Direction
1	157	SE	299	SE	176	SE
2	213	NW	192	SW	213	SE
3	276	N	248	N	142	NE
4	167	SE	387	NE	122	NE
5	240	SE	264	NW	96	SE
6	147	NW	58	SE	127	SE
7	405	NW	197	SE	148	NE
8	117	SE	227	SE	92	NE
9	285	SE	154	SE	117	SE
10	257	NW	162	SE	112	SE
11	371	NW	205	SE	63	N
12	344	NW	203	SE	99	SE
13	82	SW	230	SE	100	SE
14	248	SW	182	SE	136	SE
15	326	NE	200	NE	184	SE
16	107	SE	183	NE	294	SE
17	326	SE	191	E	253	SW
18	161	SE	185	SE	121	NW
19	273	NW	140	SE	64	SE
20	192	NW	83	NW	251	S
21	105	SE	161	NW	237	E
22	109	SE	87	NE	124	NE
23	218	SE	159	NE	108	SE
24	313	SE	179	NE	206	SE
25	186	NE	140	SE	244	SW
26	106	NE	208	SE	165	NW
27	49	SE	239	SW	76	SE
28	127	SE	246	SE	101	SE
29	276	NW	216	SE	124	SE
30	180	SE	160	SE	165	SE
31			163	SE		
Total	6363		5948		4460	
Mean	212		192		149	
21-year mean	227		184		175	

As previously mentioned, it appears that the initial general infection must have taken place during the last week of April. As shown in Figure 3, both temperature and humidity were favorable during this period, and dew was present nearly every morning. Following this initial infection, the temperatures were not so favorable during the first week of May. On May 7 the first rust was observed and from that time supplied inoculum for spread of the disease. Following this initial appearance of the disease, environmental conditions were exceptionally favorable throughout the remainder of the growing season for development and spread of rust.

Wind Movement: Because of the importance of wind movement and direction in the spread of rust to other wheat-growing areas, no report of meteorological conditions would be complete without reference to wind movement. The total wind movement for each daily 24-hour period from April 1 to June 30 is given in Table 2.

Wind movement during April, May, and June was nearly normal; there were no great extremes, although there were several days when it was strong enough to carry rust spores long distances.

Previous to the initial general infection at Denton, Texas, fairly strong winds from the south occurred on April 5, 9, 19, and 24. Later in the season there were a number of days when the wind could easily have carried spores to states to the north of Texas and thus contribute to the national epidemic.

Crop-Growth Factors Favoring Stem Rust Infection

The late maturity of the wheat crop in north Texas was one of the most important factors in the severity of the disease in the State and provided inoculum over a long period for spread to states to the north. In Table 3 dates of heading, date of ripening, and length of fruiting period are given for the years 1933 to 1935, inclusive, for the varieties of wheat grown in the field-plat variety tests at Denton.

Lateness of Heading: Date of first heading in 1935 was from 2 to 15 days later than in the spring of 1934, a fairly normal season. This late heading in 1935 resulted from a combination of several factors. Stands were thin as a result of winterkilling. The meteorological factors previously discussed, namely, excessive precipitation; cool, cloudy weather; and high humidity, combined with the thin stands, caused continued vegetative growth. The retarding effect of these factors was very evident in the manner in which the grain headed. Although wheat varieties normally reach full head in 3 to 5 days after first heads appear, in 1935 the plants were not fully headed until 8 to 13 days after

Table 3. Date of heading, date of ripening and length of fruiting period of winter-wheat varieties grown at Denton, Texas, 1933 to 1935, inclusive.

Variety	T.S. No.	C.I. No.	1933 Date First head	1933 Date Fully ripe	1933 Fruiting period, days	1934 Date First head	1934 Date Fully ripe	1934 Fruiting period, days	1935 Date First head	1935 Date Fully ripe	1935 Fruiting period, days
Early blackhull	15838	8858	4-27	5-30	33	4-24	6-1	38	4-29	6-3	35
Quivira	15833	8886	5-3	6-6	34	4-28	6-2	35	5-3	6-11	39
Sutton	15832	10053	5-12	6-8	27	5-7	6-6	30	5-14	6-17	34
Denton	9236	8265	5-9	6-8	30	5-5	6-6	32	5-16	6-17	32
Mediterranean	3015-81	10086	5-8	6-9	32	5-1	6-3	33	5-16	6-17	32
Mediterranean	3015-105-1	11587	5-8	6-7	30	5-2	6-2	31	5-11	6-14	34
Mediterranean	5933-20	10085	5-6	6-4	29	4-29	6-2	34	5-8	6-14	37
Mediterranean	5933-23	11525	5-6	6-6	31	5-2	6-4	33	5-11	6-14	34
Mediterranean	5933-34	11526	5-6	6-4	29	4-30	6-3	[illegible]	5-8	6-14	37
Mediterranean	5933-38	-	5-5	6-4	30	5-1	6-4	34	5-9	6-13	35
Nebraska 60	15835	6250	5-12	6-10	29	5-9	6-9	31	5-14	6-17	34
Kharkof	16830	1442	5-12	6-9	28	5-9	6-9	31	5-13	6-18	36
Blackhull	7172	6251	5-9	6-7	29	5-7	6-7	31	5-12	6-15	34
Kanred	11763	5146	5-10	6-7	28	5-9	6-8	30	5-11	6-14	34
Tenmarq	12578	6936	5-8	6-7	30	5-7	6-6	30	5-10	6-15	36
Fulcaster	7082	6471	5-9	6-7	29	5-6	6-7	32	5-12	6-16	35
Clarkan	20400	8858	5-8	6-6	29	5-7	6-6	30	5-12	6-17	36
Harvest Queen	15837	6199	5-10	6-8	29	5-7	6-6	30	5-12	6-15	34
Kawvale	12577	8180	5-8	6-7	30	5-5	6-6	32	5-13	6-17	35
Mean length of fruiting period					30			32			35

the first heads emerged. The average date of first heading was about May 10, whereas the mean date of full heading was May 22, or 12 days later.

Delayed Maturity: As previously discussed, the excessive precipitation, high humidity, and cool temperatures continued throughout May and most of June. These conditions, together with thin stands, delayed the maturity of the grain. As shown in Table 3, the date of ripening in 1935 is in most instances 10 to 15 days later than in 1934. The wheat crop really did not mature even at this late date, but in most instances ripened because of rust damage. Harvest of small grains in the Denton area usually begins in late May and is nearly complete by June 10. In 1935 harvest of the experimental plots was not possible until June.

The above ecological conditions, which retarded the heading and ripening of the grain, were also favorable for the development of a stem-rust epidemic. The early infection and subsequent long period of development resulted in severe damage to the grain. The long period of development for rust was also a very important factor in the spread of rust to states to the north.

Effect Of The 1935 Stem-Rust Epidemic On Wheat Yields

In Table 1 the date of first appearance of rust, the mean infection, and the range of infection at the end of the season for the years 1931 to 1935 are given. In years prior to 1935, stem rust was not a major factor in reducing yields excepting those of certain very susceptible varieties. Often stem rust does not reach its maximum until the crop is almost mature and in such years the infection may be fairly high, but the damage to the grain is relatively small. In 1935, however, the amount of initial inoculum apparently was great, and, as conditions were very favorable for spread from the time the first rust appeared, varieties were soon highly infected. Furthermore, the late maturity of the crop enabled the rust to develop and spread, while the host plants were in a very susceptible condition, resulting in severe damage to the host plants. Estimates of stem rust were made on two dates in 1935. The first reading was made on May 29 about a week after wheat had reached full head. The second reading was made near maturity. Agronomic data on rust infection, winter survival, yield of grain, and test weight of grain are given in Table 4.

Yield and plumpness of grain as indicated by test weight were closely associated in 1935 with early maturity and susceptibility to stem rust. Extremely susceptible varieties, such as Fulcaster, Harvest Queen, Sutton, and the Mediterranean strains, were highly infected with

Table 4. Yields and agronomic data for winter wheat varieties grown at Denton, Texas, 1935.

Variety	T. S. No.	C.I. No.	Date first head	Estimated percent winter survival	Percent Rust: Leaf	Percent Rust: Stem 5-29	Percent Rust: Stem Maturity	Yield of grain Bu. per acre	Test weight lbs.
Early Blackhull	15838	8856	4-29	42	58	3	20	14.1	55
Quivira	15833	8886	5-3	67	13	7	65	13.1	50
Kanred	11763	5146	5-11	82	75	7	60	8.8	45
Kharkof	16830	1442	5-13	90	85	9	90	8.7	44
Mediterranean	5933-20	10085	5-8	63	25	57	80	8.6	46
Clarkan	20400	8858	5-12	68	55	55	90	8.6	50
Mediterranean	5933-34	11526	5-6	57	13	68	80	8.3	43
Mediterranean	5933-38	-	5-9	48	6	78	90	8.0	46
Kawvale	12577	8180	5-13	50	4	20	80	7.6	40
Turkey Selection	20374	10016	5-9	78	99	8	85	6.9	46
Blackhull	7172	6251	5-12	58	70	15	75	6.9	48
Tenmarq	12578	6936	5-10	67	33	25	75	6.7	38
Nebraska 60	15835	6250	5-14	83	90	32	90	5.0	46
Fulcaster	7082	6471	5-12	40	45	48	99	4.9	42
Harvest Queen	15837	6199	5-12	62	99	55	99	4.5	47
Mediterranean	5933-23	11525	5-11	47	6	85	99	4.5	44
Mediterranean	3015-105-1	11587	5-11	52	4	99	99	3.4	40
Sutton	15832	10053	5-14	40	38	58	99	3.4	41
Denton	9236	8265	5-16	32	13	40	99	2.7	39
Mediterranean	3015-81	10086	5-16	25	48	45	99	2.0	40

stem rust by May 29, or by the time they reached full head. The resulting yield was very low and test weight extremely low. Another factor that contributed to the low yield and late maturity of these strains was the lower survival. The thin stands not only retarded the development of the wheat plants, but also contributed to the low yield. The two early varieties, Early Blackhull and Quivira, were able to produce a fair yield of grain because of their ability to mature ahead of the severe rust epidemic. Kanred wheat showed some resistance to stem rust, at least in the early stages of the epidemic. Turkey Selection C.I. 10016 produced a low yield in spite of rather light stem rust infection and high winter survival. This was no doubt due to its extreme susceptibility to leaf rust.

Conclusion

In conclusion, it should be stated that no one factor of weather or condition of the crop was responsible for the severe rust epidemic. All the factors studied contributed their respective parts and, because of the manner in which they were associated resulted in one of the most severe rust epidemics in history. These factors also played their parts in the spread of the disease to other wheat-growing areas. Had the acreage of wheat in north central Texas not been reduced by winter-killing, the loss would have been even more serious.

Under the existing conditions, which included thin stands; late maturity of the crop as a result of thin stands, excessive precipitation, and high humidity; favorable temperatures and humidity for rust development; frequent dews; cloudy weather; and favorable winds to carry the rust spores to other localities and states; the rust epidemic in Texas served as a source of inoculum for an extremely long period of time and thus contributed to the epidemic in other states.

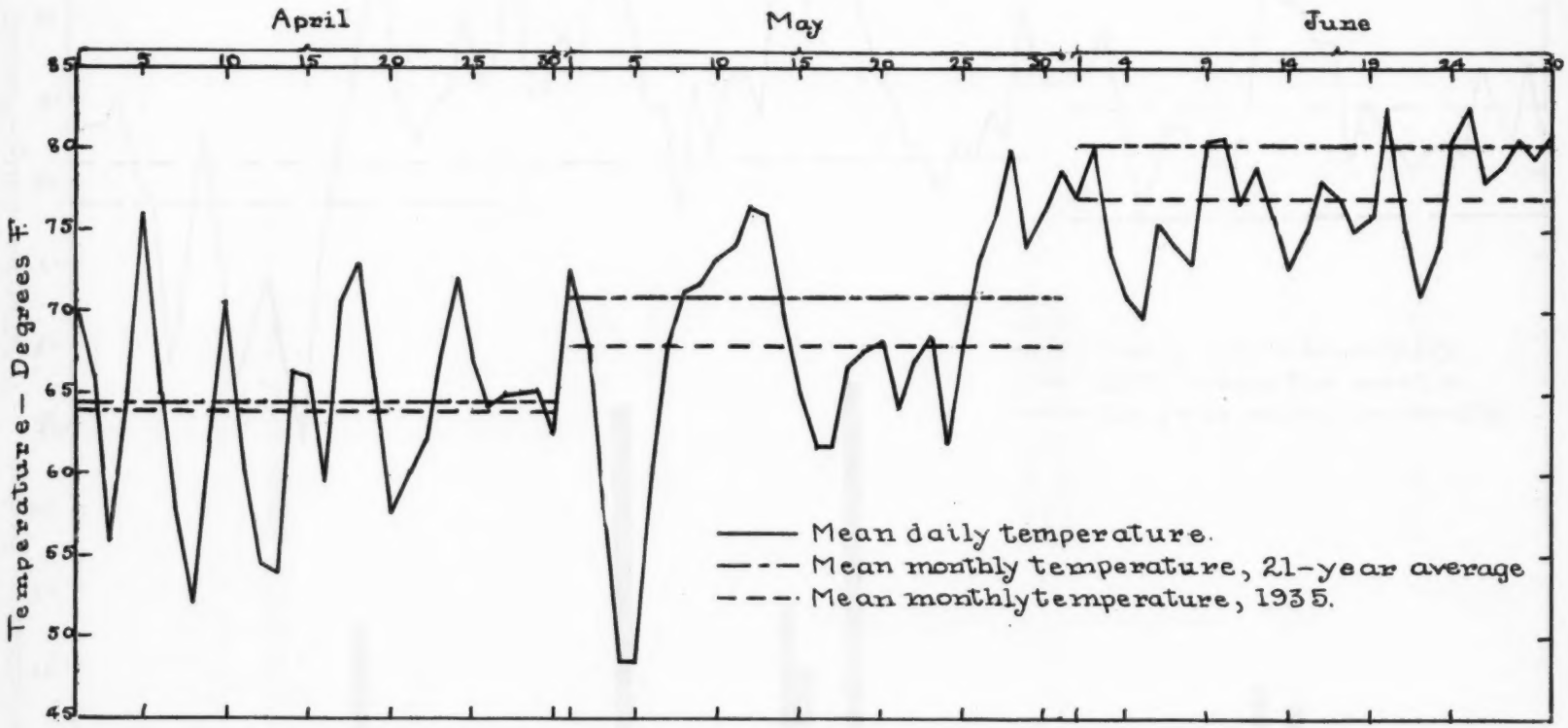

Figure 1 Mean daily temperatures, April, May, June, 1935, at Texas Substation No. 6, Denton, Texas.

April
May
June

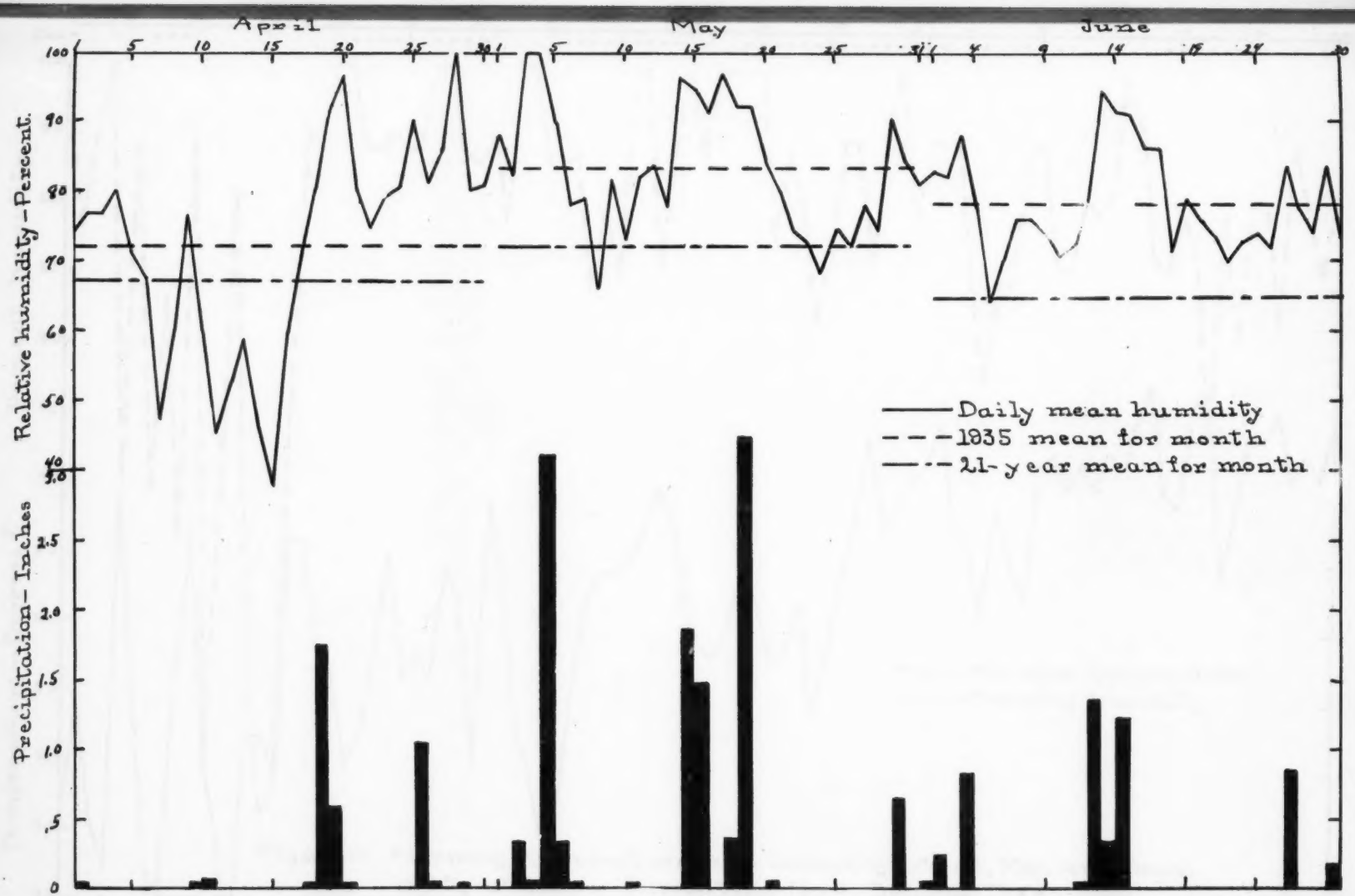

Figure 2. Mean daily relative humidity and precipitation, April, May, and June, 1935, at Substation No. 6, Denton, Texas

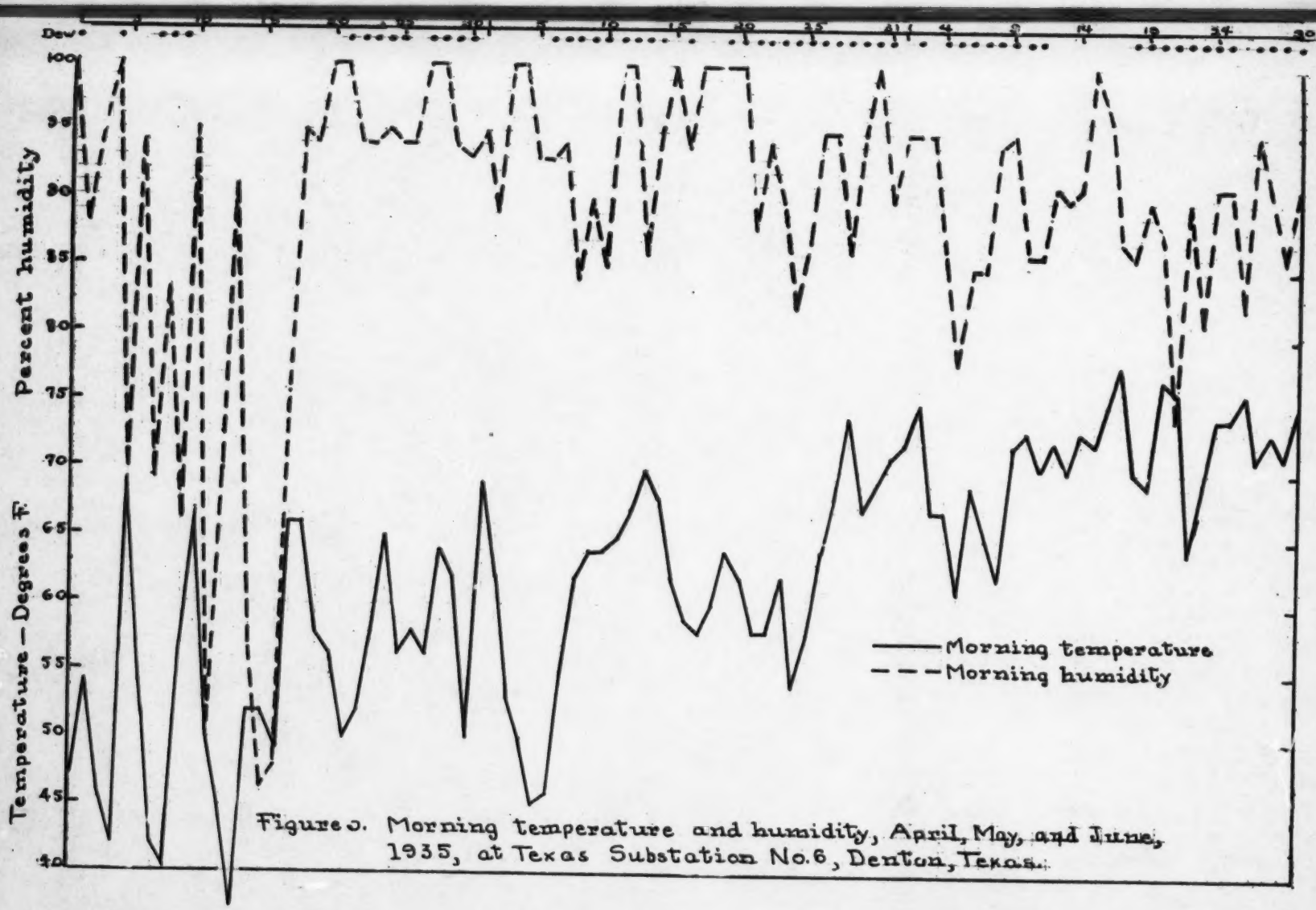

Figure 3. Morning temperature and humidity, April, May, and June, 1935, at Texas Substation No. 6, Denton, Texas.